From establishment to re-establishment: a field evaluation of sub clover cultivars

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Abstract
Sowing an appropriate cultivar of subterranean (sub) clover is important for successful dryland farming systems. Sub clover is a winter legume with potential to produce high quality herbage early in spring, for lactating animals. To be economically viable, sub clover cultivars must be competitive at establishment, accumulate biomass early in spring and produce sufficient number of seeds for regeneration in the following year. A field experiment in Canterbury, New Zealand, compared 15 sub clover cultivars in relation to a white clover ‘Nomad’ treatment after mid-April establishment. Sub clovers produced twice the total dry matter (4200 kg DM/ha,) of ‘Nomad’ (1190 kg DM/ha) from sowing to November. The highest yielding cultivars were ‘Woogenellup’ and ‘Antas’, which produced a total of ~8000 kg DM/ha. The sub clovers were more efficient at competing with weeds compared to the white clover (e.g. 50% versus 6% clover ground cover). Seed production differed among subspecies with the *yanninicums* producing fewer seeds (~ 6000 seeds/ m^2) than the *subterraneum* and the *brachycalcycinum* (~ 8630 seeds/ m^2). Seed yield ranged from 330 kg/ha (Campeda) to 1050 kg/ha (Woogenellup) kg/ha. By March the following year, ‘Narrikup’, ‘Antas’, ‘Mount Barker’ and ‘Woogenellup’ had the highest seedling regeneration (1000 seedlings/m^2) in contrast to only 182 seedlings/m^2 for ‘Monti, ‘Leura’ and ‘Rosabrook’.

Keywords
Yield, re-seeding, dryland, seed set, seed yield.

Introduction

In New Zealand, perennial white clover (*Trifolium repens* L.) is the main clover sown. However, in dryland regimes white clover fails to persist (Dodd et al. 1995; Lucas et al. 2015). Sub clover (*Trifolium subterraneum* L.) has been promoted as a viable alternative dryland pasture legume to provide early season feed before white clover is growing and is the most widely used annual clover in New Zealand pastoral systems. However, the commercial cultivars available are of Australian origin and require investigation to identify those most suitable for New Zealand conditions. In this study, cultivars were compared for their ability to establish, produce dry matter (DM), reproduce and re-establish the following autumn at Canterbury, New Zealand where evapotranspiration normally exceeds rainfall for more than 5-8 months in the year.

Methods

Site and experimental design

The experiment was at the Field Research Centre, Lincoln University (43°38'57"S, 172°28'04"E, 11 m.a.s.l.). Fifteen lines of sub clover (Table 1) and one white clover (‘Nomad’) were sown in a randomized block design (April 16, 2015) with 4 replicates. The soil was a Wakanui silt loam with available water-holding capacity of ~150 mm/m. Olsen Phosphorus level was 13 mg/L and pH (H_2O) was 5.4. Long-term annual average rainfall is 630 mm. Annual Penman potential evapotranspiration is 1094 mm and exceeds rainfall from September to April which results in a long-term potential soil moisture deficit of approximately 500 mm. The area was cultivated prior to bare non inoculated seeds being broadcast by hand and raked in to plots of 4 m^2. Sowing rates were 20g of seeds/m^2 for the sub clovers and 10 g of seeds/m^2 for ‘Nomad’. Sufficient rain (44 mm) occurred on 28th April. The commercial seeds were purchased from local suppliers and their characteristics are presented in Nichols et al. (2013).The non-commercial New Zealand line ‘Whatawhata’ (nucleus seed AK1332, Grasslanz, New Zealand) was selected based on previous evaluations by Widdup and Pennell (2000).

Clover coverage (%) and above ground biomass (kg DM/ha)

Plots were visually assessed in August (110 days after sowing) for clover coverage using a 1-100% scale: 1 indicated low sown clover coverage and 100% total coverage by the sown clover. Biomass was measured from 2 quadrats of 0.1 m^2 each above ground (20 mm) on the 28th September 2015. After that plots were mechanically cut and carried to simulate grazing. The subsequent regrowth was measured on 17th November 2015. The herbage was sub-sampled, the portions of sown clover and weeds were dried in a force-draught oven at 60°C to constant weight. Plots were then left to set seed and dry out from late November 2015.

Table 1. Summary of sub clover subspecies and cultivars used in the experiment.

Cultivar	Subspecies
'Campeda'$_{M,5}$,'Coolamoon'$_{L,5}$,'Denmark'$_{L,2}$,'Karridale'$_{L,2}$,'Leura'$_{L,2}$,'Mount Barker'$_{L,1}$,'Narrikup'$_{M,3}$,'Rosabrook'$_{L,5}$,'Seaton Park'$_{M,5}$, 'Whatawhata'$_{L,na}$,'Woogenellup'$_{M,1}$	*subterraneum*
'Antas'$_{L,3}$	*brachycalcycinum*
'Monti'$_{M,2}$, 'Napier'$_{L,5}$, 'Trikkala'$_{M,2}$	*yanninicum*

Subscripts indicate flowering time (Early, Medium, Late) and hardseededness (0-10).

Sub clover seed yield and regeneration in subsequent summer – autumn

Sub clover burrs were sampled on 12th January 2016 with a metal corer (120 mm diameter, 2 cores per plot) 0-25 mm depth. Burrs and seeds were excavated and then processed manually. The number of seeds and the seed weight (g) were recorded to estimate the seed number/m^2 and yield (g/m^2). Atypical summer rains (~ 120 mm) during late December 2015 and early January 2016 encouraged sub clover seed strike in some cultivars. Seedlings were counted on 13th January in eight 0.1 by 0.1 m quadrats of each plot and added to the seed density and seed yield values. A visual scale [from zero (no seedlings) to 5 (>1500 seedlings/m^2)] was created to develop a linear function (seedlings/m^2 = 316(score)-64, R^2=0.97) to estimate a subsequent emergence of seedlings at cotyledon - two trifoliates stage on 17th March 2016 after total accumulated rainfall of 90 mm from 14th January to 17th of March.

Climate and data analysis

From sowing to November, mean monthly air temperature was 9.4 °C recorded by a 'Hobo logger' on site. The total accumulated rainfall was 358 mm for this period (recorded 250 m from the site). Total incident solar radiation (from sowing to November) was 2233 MJ/m^2. In summer December to February) the mean monthly air temperature was 16.8 °C and total rainfall was 177 mm. Data were analysed by ANOVA in Genstat 16.0 (Lawes Agricultural Trust, VSN Ltd.). When significant, Fisher's protected least significant difference (LSD) test was used to separate treatment means.

Results and Discussion

Ground cover and above ground biomass

Yield differences were well-aligned with ground cover measurements. The highest yielding cultivars were also the most effective weed suppressors with more than 50% clover ground cover (Figure 1a). By early September (Figure 1b), the high yielding cultivars were 'Antas' and 'Woogenellup' (> 3000 kg clover DM/ha). Even larger differences in weed suppression were observed by November 2015 (Figure 1c) due to favourable temperature (mean 12.7°C) and solar incident radiation (602 MJ/m^2) experienced through October. Although most differences in cultivar performance can be attributed to cultivar performance, the low yields of 'Karridale' and 'Whatawhata' may have been caused by poor establishment and low initial seedling populations.The sub clovers closed canopy faster than white clover. Previous studies suggest that this may be due to faster leaf appearance rates of sub clover with a phyllocron of ~68 °Cd/leaf in comparison with ~89 °Cd/leaf in white clover (Moot et al. 2003). A faster canopy closure of sub clover during establishment and after defoliation allows capturing more incident light to convert into biomass, which was particularly in the cooler periods of the growth season.

Total clover yield ranged from 1800 to 8000 kg DM/ha (Figure 1d). Monocultures of sub clover 'Antas' and 'Woogenellup' had the highest (P<0.001) total yields (mean ~8000 kg DM/ha) and the lowest (P=0.001) weed yields (~1600 kg DM/ha,). 'Nomad' white clover and sub clovers 'Monti', 'Karridale', 'Trikalla and 'Whatawhata' had the lowest yields (mean ~1800 kg DM/ha) and highest weed yields (mean ~4000 kg DM/ha).

In addition, differences in canopy architecture may also explain the good performance of ‘Antas’ and ‘Woogenellup’. Both cultivars had long petioles and large leaves which contribute to light interception. Further work could quantify the extent by which these morphological differences contribute to seasonal light interception. These two cultivars, which have medium to late flowering characteristics, showed contrasting seasonality of production by accumulating biomass until later stages of the growth season than the early flowering cultivars.

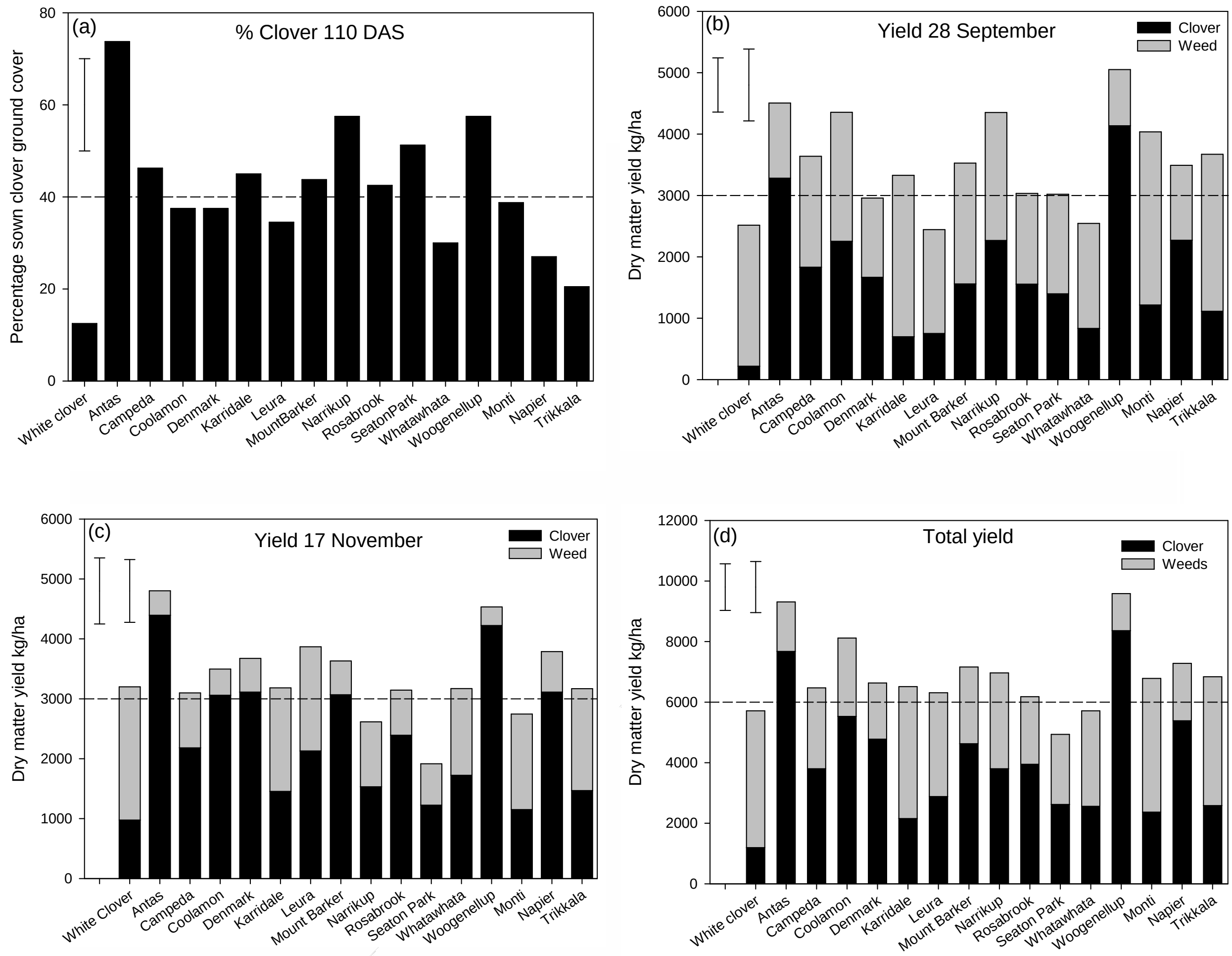

Figure 1. Mean cultivar yields of clover and weeds for the total season (a) percentage clover cover in early August 2015, (b) September 2015 harvest (c), November 2015 harvest and (d) total yield. The vertical error bars represent the LSD (*P*=0.05); where there are 2 error bars, the left one represents the lower dataset and the right one the upper dataset.

Seed yield and regeneration

The mean sub clover seed population from reseedling was 8120 seeds/m^2 (sum of unburied and buried seeds). Large cultivar differences were observed. For example, ‘Whatawhata’ (>12000 seeds/m^2) was threefold higher than ‘Campeda’ (4400 seeds/m^2, P = 0.07, Figure 2a) with ‘Woogenellup’ and ‘Mount Barker’ producing over 10000 seeds/m^2. Such differences may be large enough to influence the building up of the seedbank in their first year and affect reestablishment rates. These effects could be assessed through long term monitoring of clover stands. In our study, seed yield differed (P = 0.08) among cultivars ranging from 330 kg/ha (‘Campeda’) to 1050 kg/ha (‘Woogenellup’). The *yanninicums* clovers had the lowest seed yield (average 518 kg/ha) compared to the *subterraneums* (618 kg/ha) with ‘Antas’ having a higher (814 kg/ha) seed yield (Figure 2b).

Only 5% from the total number of seeds produced emerged in the end of the first season (January). In particular, ‘Mount Barker’, ‘Woogenellup’ and ‘Karridale’ classified as soft seed cultivars (Nichols et al., 2013) had more than 350 seedlings/m^2 emerged (P=0.009, Figure 2b). Seed emergence was largely driven by environmental conditions. A flush of seed emergence occurred after the 100 mm rainfall in

December/January 2016, an atypically high precipitation for this time in Canterbury. There were large differences in ressedling rate among cultivars. For example, 'Narrikup','Antas' ,'Mount Barker' and 'Woogenellup' had the highest (P<0.001) seedling populations of ~1000 seedlings/m^2. This is slightly lower than the thresholds identified for highest total herbage production by (Silsbury and Fukai 1977) in Australia and Smetham (2003) in New Zealand that ranged from 1000 to 1700 seedlings/m^2. The sub clovers with high seedling emergence in January could be prone to a false strike if drought condition follow. On the other hand, these early establishing cultivars have conditions for fast canopy development if weather conditions are favourable. These reinforces the idea of using a mix of complementary flowering dates and hardseededness ratings to increase resilience and optimise exposure to abiotic conditions (Lucas et al. 2015).

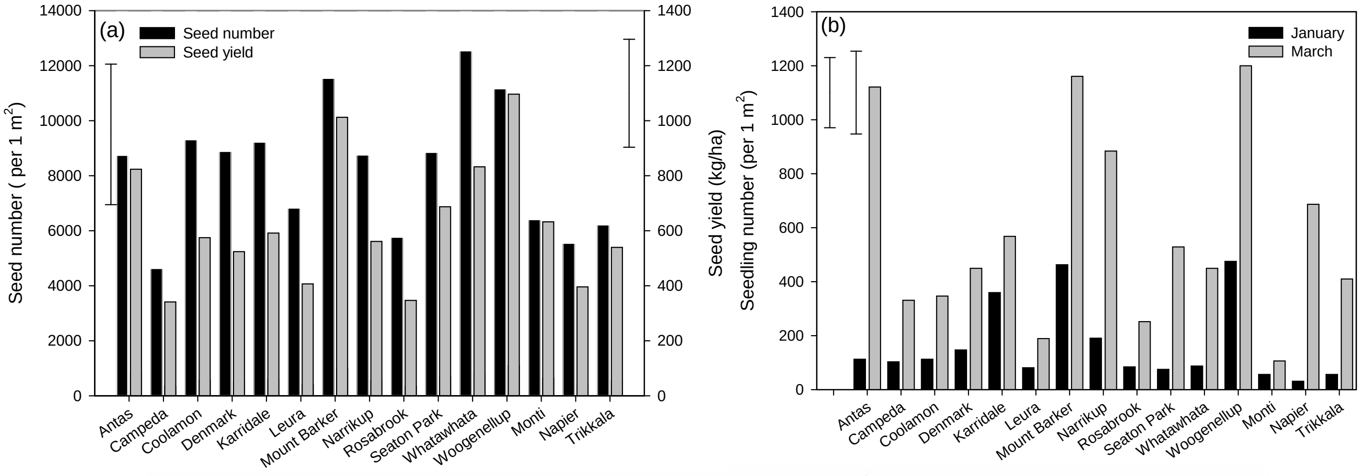

Figure 2. Mean seed number and yield of sub clover cultivars in January 2015 (A) and seedling density in January and March 2016 (B). Vertical error bars represent the LSD (*P*=0.05) with the left bar for the left column and the right bar for the right column.

Conclusion

For winter/early-spring conditions of our study, sub clover cultivars were more productive and showed higher weed suppression than white clover. There were large differences among sub clover cultivars with 'Antas', 'Woogenellup' and 'Narrikup' being the most productive and efficient to supresses weed invasion.

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